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SMITHSONIAN INSTITUTION
ASTROPHYSICAL OBSERVATORY

OPTICAL SATELLITE TRACKING PROGRAM

Carried out under a grant

from the

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Semi-annual Progress Report No. 7

CAMBRIDGE 38, MASSACHUSETTS

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July 1 through December 31, 1962

Project Director: Fred L. Whipple

Cambridge 38, Massachusetts

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1. PHOTOGRAPHIC TRACKING STATIONS

Prepared by: Jan Rolff

1. Progress during this period

Baker-Nunn satellite-tracking stations successfully photographed 17 different satellites.

The number of predictions received during the period of this report decreased by 11 percent compared with the same period in the previous year, while the number of successful photographs increased by 14 percent.

We completed new construction at the stations in Arequipa and Hawaii, and are making plans for construction improvements in Curacao. Antennas for the improved time standard were installed in India and Iran, where we now have reliable time-signal reception.

At the Florida station we completed the preliminary testing of the precision timing system manufactured by the Electronic Engineering Company of Santa Ana, California. The system is being delivered to the South Africa station for further testing.

Several stations obtained observations of ANNA, the geodetic satellite.

Although the situation is improving, we are still working to alleviate customs problems in South America.

We carried out synchronous photography and, at selected stations, continued observations of flare stars.

A. Cooperative agreements and leases for station operation

Argentina: A country-to-country agreement, executed 21 March 1962, naming as cooperating agencies the Comisión Nacional de Investigaciones Espaciales of Argentina and the Smithsonian Institution, remains in effect indefinitely.

Australia: The country-to-country agreement, executed 29 February 1960 and naming as cooperating agencies the Department of Supply of the Commonwealth of Australia and NASA, remains in effect until 28 February 1970.

Curacao: The contract between Technical Economic Council of the Netherlands Antilles and Smithsonian Institution, executed 6 October 1959, remains in effect. The Council is to be replaced by a new agency after 31 December 1962. The present agreement will continue under the new agency. The lease on the land was extended to 1 July 1963 and the annual token payment was made to the director of the Curacao Mining Company.

The Radio Telephone/Telegraph Agreement, executed 28 March 1961 between the Governor of the Netherlands Antilles and Smithsonian Institution Optical Satellite Tracking Station at Curacao, for receiving and broadcasting installation continues in effect until 28 March 1966.

Florida: The land lease, executed 18 February 1962 between the Board of Parks and Historic Memorials and the United States of America, continues in effect with automatic five-year renewals until 18 June 2001.

Hawaii: The agreement between the University of Hawaii and the Smithsonian Astrophysical Observatory, executed 3 April 1962, remains in effect until 30 June 1970, with the Smithsonian Institution having the option to renew for another 10 years.

India: The informal agreement between the Smithsonian Astrophysical Observatory and the Uttar Pradesh State Observatory, executed 26 February 1958, remains in effect indefinitely.

Iran: The informal letter of agreement, dated 1 November 1957, between the Smithsonian Astrophysical Observatory and the University of Teheran, Iran, remains in effect. Negotiations on a country-to-country agreement continue between the American Embassy and the Iranian Minister of Foreign Affairs.

Japan: The informal arrangement of 27 May 1957 between the Smithsonian Astrophysical Observatory and the Tokyo Astronomical Observatory continues.

New Mexico: An amendment to the land lease was executed 27 December 1961 between S. A. Walter and Effie Walter and Smithsonian Institution to cover a tract of land adjoining the station for use as an additional parking area. The lease remains in effect until 30 June 1976. Smithsonian Institution paid the annual rental of $250 for the period 17 December 1962 through 16 December 1963.

Peru: The agreement between the University of San Agustin of Peru and Smithsonian Institution, executed 6 October 1961, remains in effect until 6 October 1968. The $500 annual payment under the lease was made to the University of San Agustin in October 1962. The agreement executed 2 August 1961 between the Instituto Geofisico del Peru and Smithsonian Institution remains in effect indefinitely. A $75 monthly administration fee was paid to the Instituto upon presentation of receipts.

South Africa: A country-to-country agreement naming NASA and the Commonwealth Scientific and Industrial Research Organization as cooperating agencies, executed 13 September 1960, remains in effect until 13 September 1975, when it may be extended. The annual token payment of 5 shillings for the lease of the station site, covering rental up to 30 September 1963, was paid to the Secretary of Public Works, Pretoria.

Spain: The informal agreement, executed 31 August 1959, between the Observatorio de Marina and Smithsonian Astrophysical Observatory continues indefinitely.

Under the senior-observer exchange program, Henry St. Gelais, Robert Citron and Cliff Marsh were selected for temporary duty at the Uttar Pradesh State Observatory, Naini Tal, India.

B. Observer-training program

The observer-training program of four weeks at Cambridge and four weeks at the Florida station continued. During this period five observers completed their training at the Florida station.

In July, Joseph West, electronic technician, and Charles Eby, electronic development technician, were introduced to station procedures and problems, and given instruction on the clock at the Florida station.

To develop the capabilities of observers and to prepare them for possible future assignments, SAO instituted a trial tuition-refund program, in which station personnel may participate. Within certain limitations, SAO will reimburse field personnel who complete correspondence study courses or locally available extension courses for the cost of tuition.

C. Additions to station buildings

Argentina: We completed the curbing, sidewalks and paving of the station entrance, and are building drainage ditches to keep the station from being flooded when it rains. Sod is being transplanted to the area around the camera house to keep the dust down and to improve seeing. We tiled the floors of the clock and communications rooms, and completed expansion of the reduction area. Work is under way to motorize the roof.

Curacao: We are making tentative plans for construction improvements.

Hawaii: A contractor completed work on extension of the drainage ditch on 5 July. We weatherproofed the camera house and painted the outside of the building.

New Mexico: We completed installation of the roof-operating mechanism, built a retaining wall, and refurbished the workshop. Grounds work continues.

Peru: We finished painting the station.

Spain: The newly completed camera-house addition improves the station facilities. It includes electronic equipment and a workshop adjacent to the camera house, a darkroom, a film-reduction area, an office and lounge area, and a bathroom. The old building is now used primarily as a bunkroom.

2. Operations

New Mexico was the first station in the SAO Baker-Nunn network to receive ANNA flash predictions that resulted in successful observations. Special predictions were prepared for the flashing-light package. ANNA flashes were computed as times became available. We carried out synchronous photography using either object 61281 or object 62291.

In conjunction with Jodrell Bank (250' radio telescope) and Sydney (210' radio telescope), selected stations continued to make observations of flare stars. South Africa successfully observed "glints" from a mirror on the exterior of Telstar 1 (62291). At the Spanish station an automatic camera programmer has been developed for flare-star observation.

Table 1 compares the monthly operation results during the period of this report with those of the same period in 1961. Table 2 summarizes the number of passes predicted for each Baker-Nunn station, and gives the number and percent of passes successfully observed, as well as the system average for calendar year 1962. In addition 304 predictions were issued on ANNA, of which 123 observations were successful.

The operational results given in tables 1 and 2 denote field-reduced positions.

The total number of predictions for calendar year 1962 increased 14 percent over that of 1961; the total number of successful satellite observations for 1962 increased 40 percent over that of 1961.

Table 1

COMPARISON OF OPERATIONAL RESULTS

July-December 1961-1962

Number of Predictions

Month	1961	1962
July	6852	6921
August	6785	4580
September	5293	5140
October	5449	4894
November	5931	5769
December	6181	5355
Total . . .	36491	32659

Decrease in number of predictions - 11%

Number of Successful Observations

Month	1961	1962
July	1713	2435
August	2289	2301
September	2301	2085
October	1999	2290
November	1881	2480
December	2234	2278
Total . . .	12147	13869

Increase in number of successful observations - 14%

Monthly Station Average

Average/month/station	July-December 1961	July-December 1962
Predictions	507	440
Observations	169	173

Table 2
Calendar Year 1962

Summary of number of passes predicted for each Photographic Satellite Tracking Station, with the number and percent of passes successfully observed in 1962
(Compiled 15 January 1963 by Eileen C. Cavanaugh)

	New Mexico SC-1			South Africa SC-2			Australia SC-3			Spain SC-4			Japan SC-5			India SC-6			Peru SC-7		
1962	P	S	%	P	S	%	P	S	%	P	S	%	P	S	%	P	S	%	P	S	%
Jan.	524	226	43	410	158	39	415	149	36	538	139	26	524	265	51	590	179	30	363	32	09
Feb.	371	173	47	630	286	45	692	431	62	332	133	40	327	122	37	376	30	8	530	80	15
Mar.	680	339	50	654	338	52	561	349	62	651	57	9	677	243	36	633	11	2	504	133	26
Apr.	741	394	53	571	314	55	580	290	50	701	116	17	748	211	28	778	61	8	510	115	23
May	558	343	61	522	425	81	439	256	58	543	104	19	578	74	13	483	47	19	386	247	64
June	478	323	68	429	349	81	488	336	69	421	198	47	438	50	11	511	28	5	409	215	53
July	734	254	35	395	302	76	385	213	55	762	296	39	766	92	12	712	42	6	315	214	68
Aug.	363	242	67	587	462	79	462	279	60	379	202	53	389	138	35	342	12	4	302	189	63
Sept.	466	171	37	489	338	69	391	228	58	456	157	34	474	102	22	454	62	14	328	95	29
Oct.	387	260	67	466	255	55	497	250	50	405	74	18	406	114	28	373	139	37	428	192	45
Nov.	513	276	54	482	185	38	437	305	70	532	175	33	527	149	28	523	278	53	430	176	41
Dec.	414	230	56	594	248	42	521	361	69	445	119	27	431	195	45	415	233	56	473	74	16
Total	6229	3231		6229	3660		5868	3447		6165	1770		6285	1755		6190	1122		4978	1762	
Av/mo.	518	269	48	518	305	59	489	287	62	514	148	30	524	146	29	516	94	20	415	147	38

SC = number of camera; P = predictions; S = successful observations; % = percent of passes successfully observed

Table 2 (Continued)

	Iran SC-8			Curacao SC-9			Florida SC-10			Argentina SC-11			Hawaii SC-12			Total	Total	Percent
1962	P	S	%	P	S	%	P	S	%	P	S	%	P	S	%	P	S	%
Jan.	557	235	42	459	160	35	548	153	28	422	63	15	463	265	57	5813	2024	.35
Feb.	371	84	23	347	155	45	361	104	29	736	182	25	334	109	33	5407	1889	35
Mar.	661	169	26	482	130	27	609	145	24	568	195	34	522	162	31	7202	2271	32
Apr.	739	169	23	522	182	35	757	197	26	560	68	12	599	290	48	7806	2407	31
May	521	164	31	404	61	15	481	152	32	424	175	41	469	201	43	5808	2249	39
June	516	313	61	457	98	21	518	120	23	496	192	39	523	326	62	5684	2548	45
July	726	271	37	458	183	40	674	206	31	379	164	43	615	198	32	6921	2435	35
Aug.	329	133	40	300	111	37	343	93	27	451	217	48	333	223	67	4580	2301	50
Sept.	456	248	54	363	93	26	451	129	29	402	196	49	410	266	65	5140	2085	41
Oct.	389	284	73	295	122	41	396	122	31	515	254	49	337	224	66	4894	2290	47
Nov.	504	244	48	416	157	38	506	96	19	442	217	49	457	222	49	5769	2480	43
Dec.	414	172	42	347	131	38	393	124	32	536	207	39	372	184	49	5355	2278	43
Total	6183	2486		4850	1583		6037	1641		5931	2130		5434	2670		70379	27257	
Av/mo.	515	207	42	401	132	33	503	137	28	494	178	37	453	223	50	5865	2271	40

System Average for 1962 - 40%

3. Equipment and instrumentation

Basic equipment in use at the stations operated satisfactorily with routine mechanical and electrical maintenance.

A. Station vehicles

We ordered an Ambruster crew-cab conversion for a Chevrolet pickup truck for the Peru station, and took delivery at the Arkansas factory. We chose this conversion for its combined passenger- and freight-carrying characteristics.

A purchase order for a Volkswagen double-cabin pickup for Curacao is being processed.

We are initiating purchase of a Ford pickup with a crew-cab conversion for Argentina.

In choosing each overseas station truck, we have considered the availability of parts and service. In Spain, we have had difficulty in recent months in getting proper servicing for the station vehicle.

B. Mechanics and optics of Baker-Nunn camera

We have procured three BK-7 glass blanks for corrector cell protective windows, and have obtained a new desiccator compressor for New Mexico. The camera mechanical systems continue to deteriorate, but routine repair and adjustment are holding the process in check. The cameras in Peru and Hawaii required major maintenance.

To maintain closer adjustment of camera focus, we have initiated routine focus checks, which are reviewed and compared in Cambridge as well as in the field.

C. Timing system

The first phase of field testing of the prototype precision timing system was successfully completed at the Florida tracking station on 6 December 1962. No major change in the system appears necessary, although several minor modifications should be made.

We are continuing the program to improve the operation of the Norrman Time Standard.

Voltage regulators have been installed in Iran, India, and South Africa. In India and Spain we have begun using oscilloscopes for improved time-signal interpretation, and have installed improved oscillators manufactured by Sulzer Laboratories.

Norman Deegan modified the Norrman time standard at the Spanish station for installation of the Sulzer oscillators. As this was the first unit modified for this installation, we took notes for future installations and for a technical memorandum on the subject. The modification was successful, and the Norrman time standard was left operating on a Sulzer model 2.5 crystal oscillator.

The Norrman time standard in Iran has been modified for installation of a similar oscillator. Improved antenna installations for time-signal reception have been put into use in Iran and India, giving us reliable reception from these stations.

D. Instrumentation studies

We have established a program for analysis of camera focus and vibration.

Peter Brand has started work on a catalogue of vibration signatures of the several cameras. We hope that these will lead to the elimination of the camera vibration problems.

The automated film-processing machine, built by Gustaf van Loon at the Florida station, has proved unsuitable for installation at all stations because of its size and the difficulties in building it overseas.

The study of timing inaccuracies continues as part of a program to detect and correct sources of major difficulty in the existing equipment. Incoming timing data are particularly scrutinized in an effort to improve operating procedures.

We are making a technical development study on a modified aerial camera designed by Dr. James Baker for satellite tracking. The camera will provide precise position measurements of the satellite against the star background, allowing the reduced positions to be used for geodetic measurements. The camera has the unique feature of allowing the plate to be moved across the focal plane in a manner corresponding to the satellite's motion across the sky. This is in contrast to having the complete camera follow the satellite. Additional features of the camera are the equatorial mount, the linear chopper for producing breaks in the images, and the chopper calibration system.

Dr. George Veis is establishing a test site at the University of Athens, Greece. Technical development of the mechanical and electrical components is being carried out at the Smithsonian Astrophysical Observatory headquarters in Cambridge.

Flare-star observations continue in cooperation with the Jodrell Bank Experimental Station. The stars EV Lacertae and UV Ceti were observed for a total of 101 hours. Reduction is continuing, although we have not yet been completely successful in correlating radio and optical data. We noted several other optical events.

In December we began a parallel project in cooperation with the Commonwealth Scientific and Industrial Research Organization Radio Facility in Sydney, Australia. We obtained 5 hours of coverage with one possible correlation of events.

We made a microdensitometric study of Baker-Nunn films and a preliminary correlation of image density, exposure level and processing effects. We will do further work in this area when installation of a processing experimentation laboratory is finished. We completed further work on the limiting magnitude of the Baker-Nunn cameras, and are preparing a report.

The Baker-Nunn cameras photographed comets Seki-Lines and Humason. The films will be used to further Observatory studies of the structure of comets.

Sensitometric quality control was delayed for lack of experimental facilities which are now being prepared in Cambridge.

4. Logistics

We have continued to supply stock items to all 12 tracking stations. Transporting supplies to the stations and films from the stations presented no difficulty.

The assistance of the American Embassy greatly facilitated customs clearance of supplies to Argentina.

We shipped 340,745 feet of Baker-Nunn camera film to the various stations, together with enough photochemicals to process this amount of film.

Florida: The EECo Timing System was tested for a period of five weeks and proved satisfactory. It is being shipped to South Africa for further testing.

New Mexico: The spare slave-clock chassis was installed.

Peru: Since the station received and installed a coaxial cable, it is now operating with its new directional antenna, and communications with Lima have been excellent.

5. Personnel

A. Changes

During this period the following staff members of Station Operations Division resigned: Fred McCallum, Curaçao station chief; Gustaf van Loon, Jupiter station chief; Claude Knuckles, observer at New Mexico; Paul Wankowicz, observer at Iran; Henry St. Gelais, observer at Naini Tal, India; Frank Ives, observer at New Mexico; and George Hylkema, observer at Hawaii.

Jan Rolff replaced Richard C. Brock as chief of the Station Operations Division; Ronald LaCount, former New Mexico station chief, joined the Headquarters staff as operations officer; Norman Deegan as electrical engineer; and Peter Brand, as mechanical engineer. Two secretaries also joined the staff.

The six new observers recruited and trained during the previous period were assigned to the following posts: David Tewksbury to the Arequipa station; David Hallenbeck to the Curacao station; Carlton Bennett and Stephen Criswell to the Florida station; Arthur Olsen to the station in San Fernando, Spain; and Arthur Pinkham to the New Mexico station. In addition, Frank Giovane was assigned to Jupiter, Florida; Roger Carson, to Villa Dolores; and Dorik Mechau, to Hawaii.

We made the following personnel transfers during this period: Richard Bellefeuille and Frank Giovane, observers, from Florida to Curacao; Kenneth Morrison, station chief, from Curacao to Argentina; Edward Horine, station chief, from Villa Dolores, Argentina to New Mexico; Donald Tingle, observer, from Argentina to Spain where he will serve as station chief; Dale Kenyon, observer, from New Mexico to Curacao; Daniel Hanlon, observer, from Florida to Cambridge Headquarters where he serves as electrical technologist; Roy Procter, station chief, from Spain to Florida; and Henry St. Gelais, observer, from Florida to India.

As of 1 December 1962, 71 full-time Smithsonian staff observers, including 18 foreign nationals, were in the field: Argentina, 7, including 4 Argentinian nationals; Australia, 1; Curacao, 6, including 1 Netherlands Antilles national; Florida, 8; Hawaii, 6; India, 1; Iran, 6, including 4 Iranian nationals; New Mexico, 6; Peru, 7, including 2 Peruvian nationals; South Africa, 6, including 4 South African nationals; Spain, 8, including 3 Spanish nationals.

B. Travel

For travel to new assignments see the preceding section.

In August Edwin Jeffery and Peter Brand, mechanical engineers, traveled to Jupiter, Florida, to install a multiplier knob and to set up the camera for observing ANNA.

Leonard Solomon, astronomer, went to New York for the Annual Technical Symposium of the Society of Photographic Instrumentation Engineers.

In September Dale Kenyon, observer at New Mexico, and Kenneth Morrison, observer at Curacao, reported to Cambridge for temporary duty and reassignment.

In October Edwin Jeffery and Peter Brand visited the Las Cruces and Hawaii stations to test and repair equipment. Carl Hagge and Norman Deegan, staff electrical engineers, and Joseph West, electronic maintenance technician, visited the Florida station to test the new precision timing system; Mr. West remained until the middle of December to continue the testing.

Dr. Yoshihide Kozai, SAO astronomer, visited the Maui station on his return to Japan.

In November Carlton Tillinghast, SAO assistant director, made a tour of the South American tracking stations. Dr. Charles Lundquist, assistant director of research, visited the Jupiter station. Mr. St. Gelais returned from India, and Robert Citron, South Africa station chief, traveled to India for one month's temporary duty at Naini Tal. Peter Brand traveled to Peru to do camera maintenance and repair work at the Arequipa station. Carl Hagge and Norman Deegan visited the stations in Spain, Iran and India to (1) introduce Mr. Deegan to field-station operation and Cambridge support, (2) inspect the Norrman time standard and other equipment, (3) install an oscilloscope for Norrman time standard reception, and (4) perform maintenance and repair the camera and equipment at each station.

In December Cliff Marsh traveled to India for two months' temporary duty, visiting the Japan station en route.

6. Publications

Nine technical memoranda were published during this period.

No.	Title	Date	Author
2-29	Focus Plates: Discussion and Instructions	2/1/62*	Jeffery
2-30	Maintenance of Camera Focus: Weekly Tests	2/5/62*	Jeffery
2-30	Addendum	9/10/62*	Jeffery
3-17	Tektronix Oscilloscope Repair	9/25/62	Hagge
4-10	Kodak Process Control Thermometers	5/31/62*	Solomon
4-11	Test for Degree of Fixation of Film	6/12/62*	Solomon
6-21	Code 333 Revoked	8/28/62	Solomon
6-22	UFO Reporting Format	10/24/62	Peterson
7-12	Electrical and Mechanical Malfunction Logs	11/23/62	Hanlon

* Published in October 1962.

7. Future plans

We have drawn up plans for new antennas for the Argentina station to increase the efficiency of communication.

Work progresses on a new slave clock for the Baker-Nunn and the geodetic cameras to eliminate the use of a cathode-ray tube for reading milliseconds.

We are making progress on the new windows for the corrector cells. Technical specifications for the windows have been finished and sent to interested bidders.

The realuminizing of the Florida mirror has been delayed. However, we have made firm plans to realuminize the Argentina mirror in January 1963. The work will be done at the Bosque Alegre facility of the University of Cordoba.

A prototype corrector-cell protection plate is to be manufactured and eventually installed at all stations. We plan to refurbish corrector cells and mirrors at nearly all stations over a 3-year period.

The precision timing system will be tested at the South African tracking station for approximately 2 months prior to development of final specifications for production units. Over a 12-month period new oscillators are to be installed in the Norrman timing systems. These oscillators are the same type as those that will be used in the precision timing system and can be incorporated in it at a later date.

Flare-star programs will continue.

We are looking into commercial film-processing machines and processing chemistries.

II. VISUAL OBSERVING PROGRAM

Prepared by: Richard C. Vanderburgh

1. Progress during this period

The Moonwatch Program continues with 94 registered teams, having added about 200 additional satellite re-entry observing participants.

Because of the highly successful Sputnik IV re-entry operation and the diminishing scientific utility of routine visual tracking, Moonwatch placed greater emphasis on re-entry observing and fragment recovery than upon routine observing. We have begun planning to improve prediction techniques and procedures, and to equip new participants to become effective satellite re-entry observers.

Experienced observers are being encouraged to continue precision routine visual observing to maintain their proficiency and capability for special assignments, including observing preparatory for re-entry acquisition.

2. Operations

Selected teams were alerted to back up other tracking systems immediately following new satellite launches.

A special effort to observe the re-entry of Sputnik IV, coupled with fortunate circumstances, resulted in the recovery of at least one identified fragment for significant scientific research.

Sky patrols were conducted prior to the re-entries of Satellites 1962 $\iota 2$ and 1962 $\eta 3$, but only pre-entry observations were received, and these were insufficient to pinpoint re-entry times or impact areas.

Table 1 lists satellite observations received during the last half of 1962:

Table 1

SATELLITE OBSERVATIONS

Satellite	Number of Observations Received	Satellite	Number of Observations Received
1958 Alpha	177	1961 Alpha Delta 1	89
Beta 1	23	Alpha Delta 4	1
1959 Alpha 1	79	Alpha Epsilon 1	7
Alpha 2	18	Alpha Eta 1	9
Eta	64	Alpha Eta 2	1
Iota 1	222	Alpha Eta 3	7
1960 Beta 1	1	1962 Beta 3	1
Beta 2	1	Beta 4	1
Gamma 2	2	Zeta 1	4
Epsilon 1	12	Zeta 2	1
Epsilon 3	9	Eta 1	2
Zeta 1	11	Eta 3	1
Eta 3	6	Iota 1	62
Iota 1	392	Iota 2	155
Iota 2	239	Kappa 1	29
Iota 3	36	Kappa 4	1
Iota 4	39	Nu 1	9
Iota 5	15	Nu 2	8
Nu 1	24	Omicron 1	8
Nu 2	35	Omicron 2	1
Xi 1	79	Sigma 1	13
Xi 2	1	Upsilon 1	16
Pi 1	3	Upsilon 2	56
1961 Alpha 1	12	Omega 1	6
Delta 1	598	Alpha Alpha 1	25
Delta 2	4	Alpha Alpha 2	7
Delta 3	1	Alpha Gamma	7
Epsilon 1	2	Alpha Delta 1	12
Nu	59	Alpha Delta 2	20*
Omicron 1	214	Alpha Epsilon 1	256
Omicron 2	119	Alpha Epsilon 2	57
Omicron 3	10	Alpha Eta	1
The rest	67	Alpha Iota 1	3
Sigma 1	40	Alpha Iota 2	6
Upsilon	1	Alpha Kappa 1	1

*All objects after Alpha Delta were launched during this period.

Table 1(Cont.)

Satellite	Number of Observations Received	Satellite	Number of Observations Received
1962 Alpha Mu 1	6	1962 Beta Alpha 1	12
Alpha Nu 1	6	Beta Beta 2	28
Alpha Xi 1	39	Beta Delta 2	1
Alpha Xi 2	60	Beta Theta 1	23
Alpha Omicron 2	4	Beta Theta 2	77
Alpha Omicron 4	2	Beta Kappa	33
Alpha Pi 4	3	Beta Mu 1	84
Alpha Sigma	2	Beta Mu 2	10
Alpha Upsilon	9	Beta Tau 1	3
Alpha Psi	3		
		Total	3,903

The total number of observations received for each quarterly period since the beginning of the Moonwatch Program is shown in table 2.

Table 2

TOTAL MOONWATCH OBSERVATIONS, 1957 through 1962

Period	Number of Observations Received
1962	
Fourth Quarter	1485
Third Quarter	2418
Second Quarter	2582
First Quarter	1945
1961	
Fourth Quarter	2056
Third Quarter	4290
Second Quarter	3648
First Quarter	3631
1960	
Fourth Quarter	3865
Third Quarter	6621
Second Quarter	3099
First Quarter	1029
1959	
Fourth Quarter	1296
Third Quarter	1128
Second Quarter	900
First Quarter	630

Table 2(Cont.)

Period		Number of Observations Received
1958		
Fourth Quarter		1347
Third Quarter		2871
Second Quarter		747
First Quarter		1490
1957		
Fourth Quarter		1850
	Total	48,928

3. Equipment and instruments

The Project acquired more stopwatches and star charts, and redistributed M-17's and apogee scopes.

4. Logistics

Predictions and observing aids, as well as an experimental satellite calculator, have been sent to teams and re-entry observers. Special predictions for ANNA were made available to interested observers, along with the regular Ephemerides 2, 2S and 6 mailings.

5. Personnel

A. Changes

The following temporary personnel changes were made:

Astronomer Robert Martin began full-time work on the Geodetic Camera Project. Mrs. Penelope Gregory assisted Mr. Martin with clerical and secretarial work pertaining to his project.

Col. O. M. Brown was appointed acting co-ordinator.

B. Travel

During the last week in July Richard Vanderburgh traveled to a number of selected Moonwatch stations to become acquainted with observers and techniques and to discuss future Moonwatch plans and activities. He visited stations at San Jose, California; Calgary, Alberta; Chicago, Illinois; and Madison and Milwaukee, Wisconsin.

Mr. Vanderburgh presided at a dinner in Milwaukee on 19 September 1962 to present letters of commendation to Moonwatch team-leader Edward Halbach, to observers and to private citizens for their contributions in observing and recovering fragments of Sputnik IV. He traveled to

Washington, D. C., on 22 October 1962 to discuss the re-entry of Sputnik IV with Leo Abernathy at NASA. From 8-10 December 1962 he visited Moonwatch team-leader Arthur S. Leonard (Sacramento, California) to discuss organization and technical matters.

Robert Martin traveled to the Los Alamos (New Mexico) Scientific Laboratory, 8-10 September 1962 with a fragment of Sputnik IV, which was subjected to scintillation tests to determine the nature and amount of radioactivity.

6. Publications

We distributed the following publications to all stations:

Monthly Newsletters

Special Bulletins

Revised Meteor Report Forms

Revised Monthly Operational Report Forms

7. Future plans

We plan to expand satellite re-entry observing and fragment-recovery capability.

We will continue to encourage observers to maintain precision visual-observing skills in the field for special assignment capability.

Moonwatch will continue to cooperate with other agencies toward the accomplishments of their missions.

III. RESEARCH AND ANALYSIS

Prepared by: Imre G. Izsak

1. Progress during this period

Mr. Imre Izsak has extended his tesseral harmonics program by allowing for the effect of slightly erroneous station coordinates. The new computer program, operational and in continuous use by now, is capable of solving for any combination of tesseral harmonics coefficients and station corrections. At present the maximum number of unknowns is set at 20, but soon the program will be enlarged to handle cases with up to 38 unknowns. Preliminary results were obtained in several runs for tesseral harmonics coefficients up to the fourth order and for the corrections to the rectangular co-ordinates of all twelve Baker-Nunn stations. There is encouraging agreement between results obtained by running the program in different modes, and also with recent gravity-analysis data.

In order to reduce the residuals of precisely reduced optical observations, Mr. Izsak has developed a simple theory of the lunar perturbations that are for practical purposes most important--namely those with a biweekly period. These perturbations are being incorporated into the DOI program.

In a co-operative SAO-M.I.T. undertaking, the application of electronic computers to difficult algebraic manipulations is being studied. Mr. Izsak has devised a convenient method for the construction of Newcomb operators pertaining to conventional, and also to several sets of, canonical orbital elements. An extension of this project may lead to a complete analytical development of the disturbing function by a computer, thus yielding a new and extremely powerful tool for celestial mechanics.

An efficient application of the Newcomb operators calls for a fast and accurate subroutine that computes the complicated transcendental functions called Laplace coefficients and their derivatives. Mr. Izsak has experimented with various methods and has arrived at one that combines the advantages of several others.

Dr. Yoshihide Kozai has completed his investigations into the secular perturbations of asteroids with high inclinations and large eccentricities. In the case of a small ratio of the semimajor axes of the asteroid and Jupiter, Dr. Kozai has derived an analytical solution that involves elliptic functions. For large values of this ratio he obtained the solution by numerical methods. Dr. Kozai also participated in the early runs of the tesseral harmonics program.

Drs. Giuseppe Colombo and Don Lautman completed their work on the solar-radiation pressure perturbations of lunar-probe orbits. They found that it would be possible to effect a lunar capture of a probe after a flight of about 51 days. Drs. Colombo and Lautman, assisted by Miss Munford, have studied the libration orbits in the elliptical restricted three-body problem. These orbits cease to be ellipses (as in the circular restricted problem), but nevertheless they intersect a certain fixed ellipse at every pericentric passage of the two finite masses. In co-operation with Dr. Erwin Shapiro of the M.I.T. Lincoln Laboratory, Drs. Colombo and Lautman started an investigation on the problem of the concentration of dust particles near the earth. The effort consists of evaluating the following as possible mechanisms for concentration: 1) particles blasted off the moon by meteoritic impacts; 2) three-body (earth, sun, particle) capture of interplanetary particles under the influence of the Poynting-Robertson effect; 3) capture of interplanetary particles by atmospheric drag with subsequent increase of lifetime from perturbations by solar-radiation pressure. Dr. Lautman also continues his research into the distribution of the perihelion of minor planets.

Mr. Rajendra Nigam analyzed the secular decrease in the inclination of satellites Explorer I, Explorer III and Sputnik III. He found a higher rate of decrease than that predicted on the assumption of solid-body rotation of the earth's atmosphere, and computed the wind velocity that would produce such an effect at an altitude of 200 km.

Dr. Richard Giese studied optical methods for the attitude determination of cylindrical satellites. The equations derived by him allow attitude determination from the observed hypocentric coordinates of the reflection flashes and the direction of the sun above. No precise knowledge of the orbital parameters is needed and in many cases no expensive optical instruments are necessary to obtain the information on attitude.

Dr. Luigi G. Jacchia, in collaboration with Mr. Jack Slowey, has continued his analysis of the atmospheric drag of artificial satellites. Accelerations are being derived in a routine manner for six satellites, namely: Vanguard I, II and III, and Explorer I, VIII and IX. The reductions for these satellites are now complete to May, 1962. The Injun III satellite has recently been added to this list. Atmospheric temperatures above the thermopause had dropped by mid-1962 to about 750° at night and 1000° at the center of the diurnal bulge. Only a slight and safe extrapolation is needed to give the temperatures expected during the IQSY: they are 710° and 940°, respectively.

Precisely reduced Baker-Nunn photographic observations have been used for the first time to derive the fine-structure atmospheric variations connected with geomagnetic activity; the satellite employed for this purpose is Explorer IX, the 12-foot balloon. Forty-six atmospheric perturbations correlated with geomagnetic disturbances were recorded during an interval of 283 days in 1961-- an average of one every six days. The increase ΔT in the atmospheric temperature that accompanies a geomagnetic disturbance is linearly correlated with the 3-hourly geomagnetic index a_p; the maximum of the perturbation occurs systematically 5 hours later than the a_p maximum. The 12-hour oscillations in the satellite position caused by the ellipticity of the equator constituted one of the many difficulties encountered in this work. These oscillations, recognizable at first sight in all the mean-anomaly-residual diagrams, had to be corrected for as a prerequisite to the analysis.

IV. COMPUTATIONS DIVISION

Prepared by: E. M. Gaposchkin

1. Progress during this period

The position of editor of program write-ups was formally established within the division to ensure uniformity and quality of these write-ups. Under the heading Publications the program write-ups are listed. These programs include some not mentioned in the description that follows, because they are subsections of larger projects or small jobs lacking the scientific or operational stature for summary in this report. Of course all these programs are available for outside distribution, and some, of general interest and utility, are sent to SHARE.

A. Programs continued

Differential Orbit Improvement Program (DOI).--The addition of lunar-solar perturbations to the DOI Program proved more difficult than we originally thought. The first attempt was inconclusive, and the formulation has had to be reviewed. At the time of this report another theory has been implemented and checked out, and is about to be incorporated into the program. As before, these perturbations may be included as an option with any orbit, but doing this would change the definition of "mean orbital elements."

Automatic Reduction Program (ARP).--(a) Reduction program. Minor format changes have been incorporated into the program to make it compatible with the preparation program.

(b) The preparation program (defined in Progress Report No. 6). During the past six-month period we have tested it in the field, and have added to the program implementation of a time-history tape. With this magnetic tape, which contains all of the information about time corrections related to each station, the program can take the times recorded from the camera's clock and automatically make the necessary corrections to convert it to the UT 2 and A1 time systems. The final field test indicated some areas (for example, the treatment of precession) that needed improvement in the theory.

Star Catalog.--The final reprocessing of the Star Catalog was described in Progress Report No. 6. The catalog is two weeks from completion of the computer processing and preparation of the final magnetic tapes. This does not include the preparation of the star charts and the publication of the Star Catalog. However, the potential use of the catalog by an SAO project pointed to an area of the catalog that was incomplete: 20 percent of the stars in the catalog did not contain spectral types. We decided to extend the project for two months to incorporate these new data. This step requires keypunching part of the Henry Draper catalog and writing a program that will add this information to the master tape.

Simultaneous observations.--Pending the receipt of such simultaneous observations as those of the ANNA satellite, we have by using hypothetical observations found this program to be in a working condition. Some statistical studies are being made by adding normally distributed errors to the computed observations and determining how this error will propagate through the solution of the station coordinates.

Tesseral Harmonics Program.--The first version of the Tesseral Harmonics Program worked satisfactorily. It could, of course, treat an unlimited number of observations from many satellites, thereby assuring good mathematical independence of the unknowns. However, the effect of errors in the station coordinates seemed comparable with the effect of the tesseral harmonics. We embarked on a modification of the existing program to compute corrections to the station coordinates in the same solution as the harmonics. This new program is going through the final stages of checkout, and some preliminary results are available. The program is designed to determine any or all of the tesseral harmonics, and any or all of the station coordinates. With 8 harmonics and 12 stations, a 52 x 52 matrix has to be inverted. Therefore, we are incorporating a more accurate matrix-inversion subroutine.

B. New programs

Combination of Least-Squares Approximations in the Case of Correlated Variables.--Often, several different methods can be used to determine the same quantities, sometimes leading to different results. The problem, then, is to find a way to combine these different approaches to find the best solution. If the original techniques revolve around a least-squares process, then this investigation, which is completed, provides a method for combining the various solutions and their variance-covariance matrices to find the best solution of the problem. This investigation has resulted in Special Report 122 and in a computer program implementing the theory.

Laplace Coefficients Program.--In connection with a large-scale research project a very accurate and fast program is nearly completed for the computation of the Laplace coefficients and their derivatives. The program may be used in two ways--as a subroutine and for producing graphs for these complicated transcendental functions.

Ephemeris Zero.--Originally developed here at Smithsonian, Ephemeris Zero was one of the first computer programs for satellite tracking and was widely used. However, because of poor documentation and a lack of system, very little is known about the program as we use it today. We have therefore redefined and rewritten Ephemeris Zero from the beginning, using the latest orbital theory and programming techniques.

Moonwatch re-entry prediction program.--We have developed a program that will produce predictions to help Moonwatch teams observe objects during re-entry.

Automatic processing of observations received by teletype.--This concept, which has been used at other tracking agencies seems at this time to be feasible and worth-while for SAO.

Integration program.--We have begun some formal investigation of the problems relating to orbit improvement of integration. This will eventually tie in with the very accurate long-period integration program, which has made little progress during the past six months.

GEOD 2.--This program merely takes the residuals from DOI and computes the translation for the station coordinates implied by these residuals.

2. Personnel

A. Changes

New appointments include those of Miss Barbara Feit, Miss Sandra Howard, William Joughin and Miss Page Nelson as digital-computer programmers; Miss Kathleen Cotter as a keypunch operator; and Carlos Pena-Castaneda as a computations clerk.

Resignations include those of digital-computer programmers Richmond Albert, Mrs. Margo Horowitz and Miss Nancy January.

B. Travel

Miss Nancy Southmayd attended a 7090 IBSYS and 7090 IOCS Workshop sponsored by IBM in New York City from 9-13 July.

E. M. Gaposchkin and Miss Southmayd traveled to Toronto, Ontario, to attend the semiannual SHARE meeting from 9-13 September.

From 29 October through 1 November Mr. Gaposchkin was in Yorktown Heights, New York, attending the Conference on Data Handling, Reduction and Interpretation in Geophysics. From 12-14 November he attended the Sixteenth Management Development Program sponsored by the Department of Agriculture in Washington, D. C.

3. Publications

1. Southmayd, N., and Gingerich, O., CLOCK, July 1962.
2. Francis, J., and Taylor, A., FMS Express Dump, July 1962.
3. Gingerich, O., FMSMAP, August 1962.
4. Gingerich, O., BNCR - Binary Correction Loaders, August 1962.
5. Norris, R., SIMAPS, August 1962.
6. Loeser, R., GABRIEL, August 1962.
7. Benima, B., INVERS (Matrix Inversion), August 1962.
8. January, N., and Norris, R., STPL - Star Plotter, September 1962.
9. Joughin, W., CONVERSION, September 1962.
10. Gingerich, O., PACK, October 1962.
11. Gaposchkin, E. M., GEOD 2, October 1962.
12. Loeser, R., PLINT, October 1962.
13. Bakeeff, A., and Stein, M., Moonwatch Re-entry Predictions, October 1962.
14. Howard, S., COORD, October 1962.
15. Johnson, K., THT, October 1962.
16. Young, A., ULTRA-PLOT, November 1962.
17. Johnson, G. M., FTFC, November 1962.
18. Taylor, R., SCANDELDUM, November 1962.
19. Simon, N., and Wadzinski, H., MATMPY, November 1962.
20. Simon, N., ANNOTATE, November 1962.
21. Kadakia, P., SISLSQ (Super Least Squares), November 1962.
22. Young, A., LIGHTS, December 1962.

V. PHOTOREDUCTION DIVISION

Prepared by: L. J. McGrath, Jr.

1. Progress during this period

Production of precisely reduced positions continued to increase despite heavy turnover of personnel (20 percent) and diversion of resources to several special projects.

We completed modification of the five Telecordex systems in July as planned.

Through the continued efforts of the staffs of the Computations Division and Photoreduction Division, the SI-ARP preparation program was completed and pilot operations begun in December 1962.

We initiated a program for the exchange of film samples among the camera stations (for quality comparison).

2. Operations

A. Routine

The film evaluation Section received and catalogued 14,445 successful films. (The total number of films received now exceeds 75,000).

A sample, consisting of roughly 1000 films, underwent critical evaluation for quality-control purposes.

We processed 7230 films, resulting in 11,258 precisely reduced positions (in the A.1 time system).

B. Special projects

The division provided measuring assistance for Dr. Fred Fischback of the University of Michigan in connection with a refraction study project.

We provided necessary measurement data for a film-distortion study being made at SAO.

We continued to participate in the simultaneous-observing program. Frames were reduced for this project.

A series of test plates, taken with a prototype geodetic camera, was successfully reduced.

3. Equipment and instrumentation

Early in July the five Telecordex digitizers were modified to accommodate the revised measuring techniques that will be introduced with the SI-ARP Program. A suppress switch added to the x bank of each Telecordex gives the operator the option to retain any desired x accumulation while moving (rotating) the stage of the Mann engine as required. The equipment when purchased had this option in the y coordinate only.

4. Personnel

Eleven members of the staff resigned and 15 new ones were appointed. As of 3 December 1962 there were 42 full-time and 7 part-time employees in Photoreduction.

5. Publications

See Section VII of this report.

6. Future plans

Early in February 1963, our Mann 422D/32 measuring engine will be returned to the Mann Company plant for overhaul and modification.

Concurrent with the 422D overhaul, the electronic program unit associated with this engine will be adapted for plugboard operation which offers greater flexibility than the present fixed-board system.

"Auxiliary duplication" and "alternate program" features will be added to the IBM 026 keypunch units in each of the 5 measuring systems.

VI. COMMUNICATIONS

Prepared by: Charles M. Peterson

1. Progress during this period

In preparation for changing over the TWX system to direct dialing, all teletype-operating personnel attended training classes conducted by the telephone company at its downtown Boston headquarters. These training sessions were held before the nationwide conversion date of 31 August 1962. With the new system now in effect we no longer need connection through two relay points to reach our Baker-Nunn stations in Florida and New Mexico. This arrangement, of course, gives us faster, easier operation. In addition to dialing the Florida and New Mexico stations directly, the TWX dial service provides for dialing automatically any agency whose number is listed in the TWX directory.

During this reporting period two representatives of the recently established New England NASA office visited our communications center to get a firsthand look at our facilities and to discuss ways in which they might use them. They were primarily interested in communicating with NASA headquarters through our teletype lease to Goddard. Although message traffic for the NASA office here has been light so far, it will probably increase when the teletype equipment is installed and when the group gets settled in its new quarters.

In November two daily radioteletype schedules were established from NASA's minitrack station at Lima to each of the Smithsonian tracking sites in Arequipa, Peru, and Villa Dolores, Argentina, replacing the hourly schedules previously maintained. Message traffic to and from Villa Dolores is handled at 1400 and 2300 UT, and that to and from Arequipa, at 1500 and 2100 UT. Stations keep receivers on during off-scheduled times to provide for passage of operational immediate traffic. This change, which allows for more efficient use of station personnel and equipment, proved especially valuable during November and December, when the Arequipa station provided communications support for the French-Argentine sodium-vapor experiments sponsored by NASA.

Arrangements were completed to allow this center to use the GSA private teletype line between Boston and Washington. We used this privilege to great advantage for messages between the Smithsonian Institution and the Astrophysical Observatory. Savings per word are approximately 70 percent, while speed and accuracy continue to meet our maximum requirements.

Under the security officer (chief of communications) the division assumed complete control of application for processing of sensitive security clearance. The entire process from initial application, fingerprinting, and submission for investigation, to final disposition, is now regulated by the security office located in Room 231 of building B. Clearances are processed for those granted initial approval by the assistant director, and may be obtained under the Smithsonian Astrophysical Observatory with Dr. Fred L. Whipple as consultant.

2. Operations

For the six-month period of this report, the communications center handled an average of 1.6 million words per month.

3. Instrumentation and equipment

The telephone company made a study of the SAO switchboard to determine whether or not additional trunk lines are required. The surveyors saw no need for additional trunk lines, but recommended converting three of our present lines into combination trunks, which would allow for greater flexibility. Three telephone trunk lines have been converted to combination trunks.

Two power failures in Cambridge during this reporting period resulted in power loss to all teletype equipment and room lighting. Although this happened over two weekends when message traffic was light, it nevertheless caused us to lose communication with our tracking stations, with NASA and with NORAD for as long as 18 hours. We talked with officials of Harvard University and the Cambridge Power and Light Company, seeking a solution to this problem.

In December 1962, to the mutual satisfaction of Harvard and Smithsonian, a permanent alternate-feed line was installed from the auxiliary power supply in building A to the communications center in building B. Should city power break down in the future, simply throwing a switch in building A will provide emergency power to all teletype equipment and will reduce outage time to a matter of minutes.

A trouble-free Model 28 teletype machine was installed at the New Mexico camera station to replace the older Model 19 recently made inoperative by a freak lightning storm. The Model 28 is an excellent piece of equipment, known for seldom needing of repair and for quiet and smooth operation. This machine is equipped with the automatic answering device made so necessary by the telephone company's converting its TWX system to dial operation.

We have acquired a portable incinerator for disposing of downgraded and outdated classified correspondence and superseded publications.

4. Logistics

We supplied twenty boxes of teletype paper and teletype tape to the Baker-Nunn stations in Argentina and Peru.

5. Personnel

The following changes in personnel were made:

Appointed	Title	Date
Rose M. Glazer	Telephone Operator	July 23, 1962
Lorayne M. Nolan	Clerk Typist	December 26, 1962
Transferred		
Sarah L. Heintz	Clerk Typist	December 7, 1962
Employment Terminated		
June E. Smith	Telephone Operator	July 27, 1962

6. Future Plans

We plan to install a Model 28 teletype machine with an automatic answering device to replace the older Model 19 at our tracking station in Florida.

An investigation is currently under way to determine how the GSA teletype network can best be used. GSA now maintains a nationwide network serving all major cities in the United States with significant cost savings to authorized users. The Astrophysical Observatory has been declared an authorized user.

We are making plans to establish a teletype circuit between the communications center at 60 Garden Street and the offices at 185 Alewife Brook Parkway, Cambridge.

The GSA Federal Agencies Consolidated Telephone System goes into operation on a nationwide basis 15 February 1963. Leased telephone lines will be installed to serve government agencies in 42 major cities throughout the United States. In addition to the line we now have to the GSA switchboard in Boston, we plan to have two additional lines installed in order to take advantage of this low-cost telephone network.

VII. PUBLICATIONS

The Satellite Tracking Program issued the following Special Reports during this six month period:

No. 100 -- Accurate Drag Determinations for Eight Artificial Satellites; Atmospheric Densities and Temperatures, by Luigi G. Jacchia and Jack Slowey.

No. 101 -- Numerical Results from Orbits, by Yoshihide Kozai.

No. 102 -- Catalog of Precisely Reduced Observations (P-5), prepared by Jean E. MacDonald, Katherine Haramundanis and other members of the Data Section, Photoreduction Division.

No. 103 -- Satellite Orbital Data, material prepared under the supervision of I. G. Izsak.

No. 104 -- Catalog of Precisely Reduced Observations (P-6), prepared by Jean E. MacDonald and other members of the Data Section, Photoreduction Division.

No. 106 -- Catalog of Precisely Reduced Observations (P-7), compiled by Phyllis Stern, Data Division.

No. 107 -- On Some Singular Orbits of an Earth-Moon Satellite with a High Area-Mass Ratio, by G. Colombo and D. A. Lautman.

No. 108 -- On the Libration Orbits of a Particle Near the Triangular Point in the Semirestricted Three-Body Problem, By G. Colombo, D. Lautman, and C. Munford.

No. 109 -- Re-Entry and Recovery of Fragments of Satellite 1960 $\epsilon 1$, by Charles A. Lundquist, Richard C. Vanderburgh, Walter A. Munn, David Tilles, Edward L. Fireman and James DeFelice.

No. 111 -- Possible Contributions of Space Experiments to Cometary Physics, by P. Swings.